SURFACE VEHICLE RECOMMENDED PRACTICE	J2923™	DEC2024
	Issued 2016-05 Revised 2024-12 Superseding J2923 MAY2016	

(R) Inertia-Dynamometer Disc Brake Drag Measurement Test Procedure for Vehicles Less Than 4540 kg GVWR

RATIONALE

This SAE Recommended Practice is the result of an industry effort to develop inertia dynamometer test procedures to assess brake drag under a series of test schedules based on the desired application. The test allows the project or application engineer to determine or compare the amount of brake drag for a given design level or configuration. The test provides a standard method to better quantify and better understand the parasitic (drag) torque generated by the brake corner during off brake condition under repeatable laboratory conditions.

This inertia dynamometer test procedure provides four methods to quantify brake drag measurements combining light, moderate, and severe braking with a brake drag matrix. This matrix combines increasing static preconditioning pressure applications before measuring brake drag with expanded braking speeds. This test features four schedules focused on providing the user the option to perform drag evaluation specific to its purposes, and it now also includes a way to test electromechanical brakes (EMB) and brake configurations used on electric or hybrid vehicles. Data from either of these four schedules is useful to assess the influence of certain design features, determine brake sensitivity to braking speeds, and conditioning. Elements from this recommended practice are also applicable or useful for other laboratory test procedures to assess brake drag.

Due to the novelty of this SAE Recommended Practice, especially with the introduction of the WLTP brake cycle, the Task Force encourages users of this document to contact the SAE Staff Representative for the Foundation Brake Steering Committee or the Chairman of the Brake Dynamometer Standards Committee with questions and comments. This feedback will provide valuable for future revisions and updates.

This SAE Recommended Practice is intended as a guide toward standard practices and is subject to change to keep pace with experience and technical advances.

TO PLACE A DOCUMENT ORDER: **Tel: 877-606-7323 (inside USA and Canada)**
Tel: +1 724-776-4970 (outside USA)
Fax: 724-776-0790
Email: CustomerService@sae.org
SAE WEB ADDRESS: **http://www.sae.org**

For more information on this standard, visit
https://www.sae.org/standards/content/J2923_202412/

TABLE OF CONTENTS

1. SCOPE

The SAE J2923 procedure is a recommended practice that applies to on-road vehicles with a GVWR below 4540 kg equipped with disc brakes.

1.1 Purpose

Quantify brake drag using a laboratory-based procedure under various conditions and friction couple braking history. The test sequence includes driving simulation and performance-type braking events along with optional sections for hot drag evaluation and brake drag measurement for parking brake systems.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

SAE J2522 Inertia Dynamometer Disc and Drum Brake Effectiveness Test Procedure

SAE J2784 FMVSS Inertia Dynamometer Test Procedure for Vehicles Below 4540 kg GVWR

SAE J2789 Inertia Calculation for Single-Ended Inertia-Dynamometer Testing

SAE J2986 Brake Pads, Lining, Disc, and Drum Wear Measurements

2.1.2 ISO Publications

Copies of these documents are available online at https://webstore.ansi.org/.

ISO 16610-31 Geometric Product Specifications (GPS) - Filtration - Robust Profiles Filters: Gaussian Regression Filters

ISO 16610-32 Geometric Product Specifications (GPS) - Filtration - Robust Profiles Filters: Spline Filters

2.2 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Technical Report.

2.2.1 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM E4-10 Standard Practices for Force Verification of Testing Machines

ASTM E2624-09 Standard Practice for Torque Calibration of Testing Machines and Devices

2.2.2 DIN Publications

Copies of these documents are available online at https://www.din.de/en/.

DIN 51309: 2002-12 Materials Testing Machines - Calibration of Torque Measuring Devices for Static Torque

2.2.3 Other Publications

DKD-R 3-5 Calibration of Torque Measuring Devices for Static Alternating Torques

EURAMET cg-10/v.01 Guidelines on the Calibration of Static Torque Measuring Devices

ECE/TRANS/WP.29/2024/83 Proposal for a New Amendment to UN Global Technical Regulation No. 24 on Laboratory Measurement of Brake Emissions for Light-Duty Vehicles

VDA/VDE 2646 Torque Measuring Devices - Minimum Requirements in Calibrations

3. DEFINITIONS

3.1 APPARENT FRICTION FOR DISC BRAKES

Ratio of brake output torque to total input torque. Also referenced as brake effectiveness.

Per Equation 1:

$$\mu = \frac{10^6 \cdot T}{2 \cdot (p - p_{Threshold}) \cdot A_P \cdot r_{eff} \cdot \eta} \quad \text{(Eq. 1)}$$

where:

μ = apparent friction for disc brakes [unitless]

T = output torque [N·m]

p = brake pressure [kPa]

$p_{Threshold}$ = minimum pressure required to start developing braking torque; unless otherwise specified by the test requestor or measured as part of the project, use a zero value [kPa]

A_p = total piston area acting on one side of the caliper for disc brakes where the hydraulic pressure is exerted by the brake actuation system [mm^2]

r_{eff} = radial distance from centerline of the piston to the axis of rotation for disc brakes, unless other dimensions are provided by the requestor [mm]

η = caliper brake efficiency; ratio of input hydraulic force to effective force acting on the brake pad [unitless]

3.2 BRAKE DRAG

Measurable torque generated by the brake with no active or intentional input from the brake actuation system. [N·m]

3.3 BREAKAWAY TORQUE

Torque required to initiate brake rotation after cable tension, input force, or enabling command is applied (or sent) to the parking brake mechanism. [N·m]

3.4 DECELERATION-CONTROLLED BRAKE APPLICATION

Inertia-dynamometer control algorithm that adjusts the real-time brake pressure to maintain a constant torque output calculated from the instantaneous deceleration specified in the test procedure.

3.5 DISC THICKNESS VARIATION - DTV

Measurable variability of the disc variable of thickness over one full revolution.

3.6 DRUM BRAKE EFFECTIVENESS (C*)

Per Equation 2:

$$C^* = \frac{10^5 \cdot T}{2 \cdot (p - p_{Threshold}) \cdot A_P \cdot r_{eff} \cdot \eta} \quad \text{(Eq. 2)}$$

where:

C^* = effectiveness for drum brakes [unitless]

T = output torque [N·m]

p = brake pressure [kPa]

$p_{Threshold}$ = minimum pressure required to start developing braking torque; unless otherwise specified by the test requestor or measured as part of the project, use a zero value [kPa]

A_p = total piston area acting on one side of the caliper for disc brakes; total wheel cylinder area for drum brakes [mm^2]

r_{eff} = radial distance from the centerline of the piston to the axis of rotation for disc brakes; internal drum diameter divided by two for drum brakes, unless the requestor provides other dimensions [mm]

η = brake efficiency; unless otherwise indicated by the test requestor or measured as part of the project, use 100% [unitless]

3.7 GROSS VEHICLE WEIGHT - GVWR

Maximum vehicle weight indicated by the manufacturer. [kgf]

3.8 INITIAL BRAKE TEMPERATURE - IBT

Rotor temperature at the start of the brake application. [°C]

3.9 LATERAL RUN OUT - LRO

Maximum allowed brake lateral run out shall be less than 50 μm.

3.10 LIGHTLY LOADED VEHICLE WEIGHT - LLVW

Unloaded vehicle curb weight plus 180 kg for driver and test instrumentation. [kgf]

3.11 MAXIMUM PARK BRAKE INPUT FORCE

Measured or calculated force applied at the brake equivalent to 400 N input force at the cabin for hand-operated (or 500 N for foot-operated) parking brake systems. For calculated values, use the pedal (or hand lever) ratio, the cable efficiency, and the multiplying factor of the parking brake mechanism to determine the effective force acting on the brake pads. For electric park brake systems, unless otherwise specified by the test requestor, the maximum force is the nominal value at full nominal current and nominal voltage of the system. For all park brake systems, unless otherwise specified by the test requestor, use a maximum park brake input force of 1500 N.

3.12 MAXIMUM VEHICLE SPEED - V_{max}

Highest speed attainable by accelerating at a maximum rate from a standstill to a distance of 3.2 km on a level surface, with the vehicle at LLVW for vehicles per FMVSS 135 or at GVWR for vehicles per FMVSS 105. For electric vehicles, the speed attainable is determined with the propulsion batteries at a state of charge of not less than 95% at the beginning of the run. [km/h]

3.13 PRESSURE-CONTROLLED BRAKE APPLICATION

Inertia-dynamometer control algorithm that maintains a constant input pressure to the brake irrespective of the torque output.

3.14 TIRE DYNAMIC ROLLING RADIUS - RR

Tire radius that equates to the revolutions per mile (RevsPerMile) published by the tire manufacturer for the specific tire size. If unknown, the rolling radius can be calculated from the RevsPerMile value using Equation 3. Use the tire dynamic rolling radius to calculate test inertia and the dynamometer rotational speed in revolutions per minute (rpm) for a given linear vehicle speed.

$$RR = \frac{1609344}{2 \cdot \pi \cdot rpm} \quad \text{(Eq. 3)}$$

where:

RR = tire dynamic rolling radius [mm]

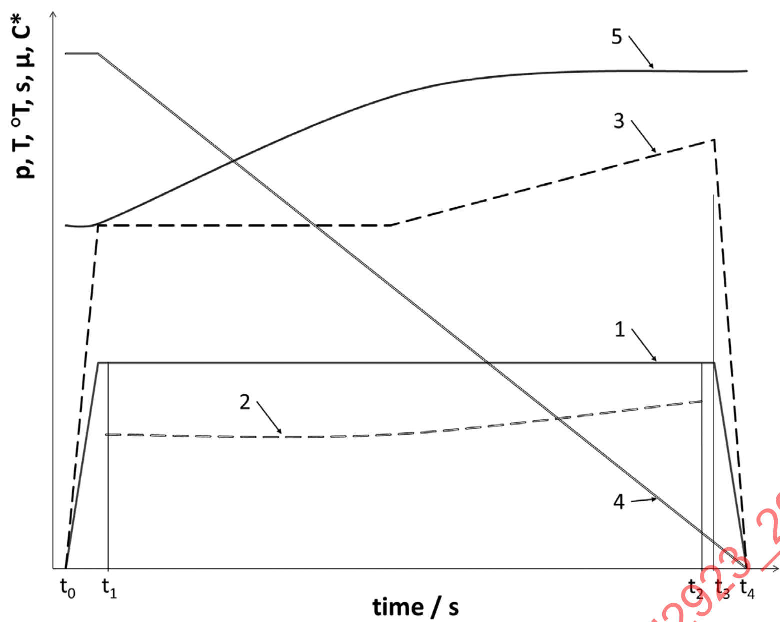
rpm = tire manufacturer specification for revolutions per mile indicated by the tire manufacturer

4. TEST CYCLES

4.1 Dynamic Brake Application

To achieve the target pressure or deceleration level during dynamic braking, use a pressure ramp rate of 5000 kPa/s.

Figure 1 illustrates the main time stamps used to characterize the brake application.



Key:
1 - Brake pressure (p)
2 - Brake coefficient of friction or drum brake effectiveness (μ, C*)
3 - Brake torque output (T)
4 - Brake speed (s)
5 - Brake temperature (°T)

Figure 1 - Typical brake deceleration (constant pressure) time stamps

4.1.1 Time t_0

Brake application initiation. At this time, the pressure starts to rise.

4.1.2 Time t_1

Time at which pressure or torque reached the target level. At this time, the brake reaches its target level for torque or pressure control. At time t_1, the calculation of average by time and the average by distance begins.

4.1.3 Time t_2

Time at the end of averages. At time t_2, the inertia-dynamometer data acquisition system terminates the average calculation by time and average by distance. Time t_2 is the end of the stable portion of the brake application. Time t_2 is when the speed is 0.5 km/h above the release speed (t_3).

4.1.4 Time t_3

Time at release speed. At time t_3, the inertia-dynamometer servo controller releases the brake (specified in 8.1.3).

4.1.5 Time t_4

Time at brake pressure and torque lost. At time t_4, pressure and torque are below the minimum thresholds. The inertia-dynamometer considers the braking event complete.

4.2 IBT Control

4.2.1 Brake Warm-Up Operation for Dynamic or Brake Drag Applications

If the temperature decreases below the IBT for the next braking condition, warm up the brake by conducting brake drag operation at 50 km/h until the brake temperature is 5 °C above the IBT for the next nominal brake application. Control brake pressure at 2000 kPa for disc brakes and 3000 kPa for drum brakes. Do not conduct brake warm-up for sections with an IBT at or below 35 °C.

NOTE 1: In cases when a brake warm-up is required for sections with an IBT at or below 35 °C (e.g., when restarting the test after a test interruption), conduct brake warm-ups at 25 km/h and control brake pressure at 1000 kPa for disc brakes and 1500 kPa for drum brakes.

NOTE 2: In cases when the dynamometer faults while performing a driving cycle (WLTP), do not perform warm-ups. Instead, restart the specific trip where the failure happened from the start of said trip.

4.2.2 Brake Warm-Up During the Fade Schedules

If the brake does not achieve the IBT (see 4.3), perform a brake drag application at 80 km/h with a torque equivalent to 1.96 m/s^2 deceleration to warm up the brake. Do not apply the warm-up procedure for more than 20 seconds.

4.2.3 Brake Cool Down

If the brake temperature is 5 °C or above the IBT of the next brake application, rotate the brake at 20 km/h until the brake cools down to within 5 °C of the IBT.

4.3 Brake Fade Temperatures

The brake fade section heats the brake in preparation for the post-fade friction and drag evaluation. The IBTs for each brake application during the fade operation use a logarithmic temperature profile per Equation 4.

$$\text{IBT}_n = \text{IBT}_1 + \frac{(IBT_{15} - IBT_1) \cdot ln(n)}{ln(15)} \qquad \text{(Eq. 4)}$$

where:

n = brake application number; between one and 15

IBT_n = initial brake temperature for the nth brake application/°C

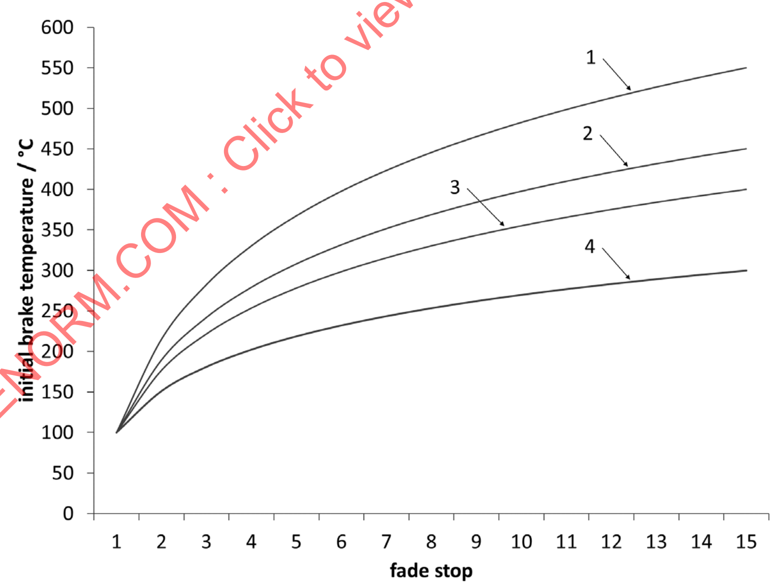
IBT_1 = initial brake temperature for the first brake application/°C

IBT_{15} = initial brake temperature for the last brake application/°C

The different fade schedules for disc or drum and front or rear brakes are shown in Table 1 and depicted in Figure 2. The optional fade schedules are more severe and provide higher temperatures. Unless otherwise specified by the test requestor, conduct the standard fade schedule and keep it the same for a given project.

Table 1 - Initial brake temperatures during fade modules

Brake type	**Disc**				**Drum**	
Axle position	**Front**		**Rear**		**Rear**	
Schedule	**Standard**	**Optional**	**Standard**	**Optional**	**Standard**	**Optional**
First initial temperature / °C	100	100	100	100	100	100
Last initial temperature / °C	450	550	300	400	200	300
Stop number	Initial brake temperature / °C					
1	100	100	100	100	100	100
2	190	215	151	177	126	151
3	242	283	181	222	141	181
4	279	330	202	254	151	202
5	308	367	219	278	159	219
6	332	398	232	298	166	232
7	351	423	244	316	172	244
8	369	446	254	330	177	254
9	384	465	262	343	181	262
10	398	483	270	355	185	270
11	410	498	277	366	189	277
12	421	513	284	375	192	284
13	432	526	289	384	195	289
14	441	539	295	392	197	295
15	450	550	300	400	200	300



Key:
1 - Disc FA optional
2 - Disc FA standard
3 - Disc RA optional
4 - Disc RA standard

Figure 2A - Initial brake fade temperatures for disc brakes

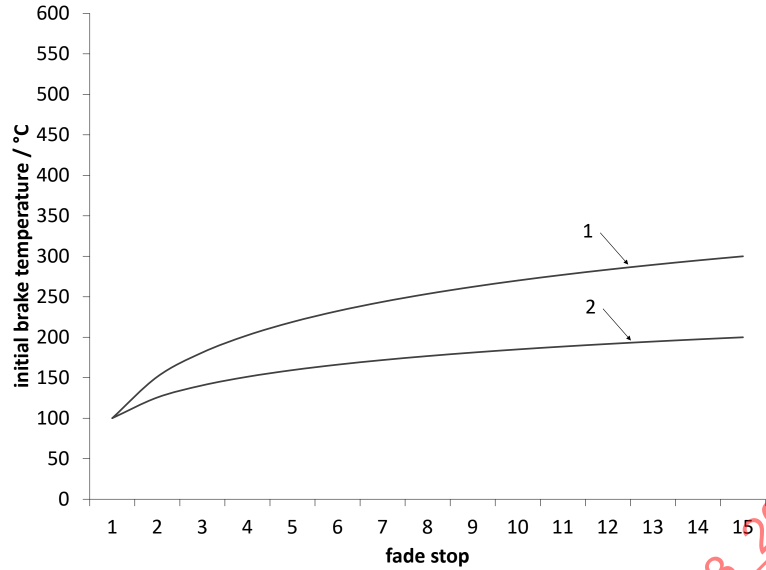


Figure 2B - Initial brake fade temperatures for drum brakes

Figure 2 - Initial brake fade temperatures for all the test schedules

5. TEST EQUIPMENT

5.1 Single-ended brake inertia-dynamometer capable of performing deceleration and pressure-controlled brake applications. Coordinate with the test requestor the option to conduct the brake drag matrix on a special-purpose test system.

5.2 Automatic data collection system capable of digitally recording the following channels at 200 Hz minimum:

5.2.1 Brake equivalent linear speed. [km/h]

5.2.2 Brake input pressure. [kPa]

5.2.3 Brake output torque. [N·m]

5.2.4 Brake drag torque. [N·m]

5.2.5 Brake fluid displacement. [mm^3]

5.2.6 Parking brake cable tension (rear brakes testing only). [N]

5.2.7 Parking brake cable travel (rear brakes testing only). [mm]

5.3 Automatic data collection system capable of digitally recording the following channels at 30 Hz minimum:

5.3.1 Brake rotor temperature. [°C]

5.3.2 Brake pad or brake shoe temperature. [°C]

5.3.3 Hub bearing temperature measured at the hub bearing. [°C]

5.3.4 Cooling air temperature, relative humidity, and speed.

5.4 Brake Drag Measurement

Use a torque measuring device with an accuracy of ±0.1 N·m from zero to 10 N·m in both directions. Report the uncertainty of measurement and the accuracy class. Reference the different standards from 2.2 for the proper calibration process, torque steps (especially when calibrating below 20% of the full-scale for the torque measuring device), calibration report, and the associated uncertainty of measurement budget, unless the specific method used for the test is agreed upon between the test requestor and the test facility. Indicate the torque measuring method in the final test report. Verify the hysteresis of the drag torque measuring system (including the influence of overhanging masses from the brake fixture) in the forward and reverse directions. When the test system (instrumentation, control, and data collection) allows, measure brake drag 4 seconds before and 4 seconds after completing the dynamic brake applications. This will allow the evaluation of brake drag at multiple speed and temperature combinations during the test.

5.5 Test fixture can use the hub and bearing assembly or a hubless fixture. Unless otherwise specified by the test requestor, ensure rotor-to-caliper mounting surface parallelism and rotor-to-fixture concentricity is within 0.050 mm. Document the fixture setup with pictures as part of the test report.

5.5.1 When using a hubless fixture with the rotor mounted on the dynamometer shaft with no physical connection to the tailstock, ensure stiffness and alignment are equivalent to the knuckle or axle assembly. Estimate the stiffness of the fixture by measuring a knuckle assembly of similar material, size, and geometry. See Figure 3.

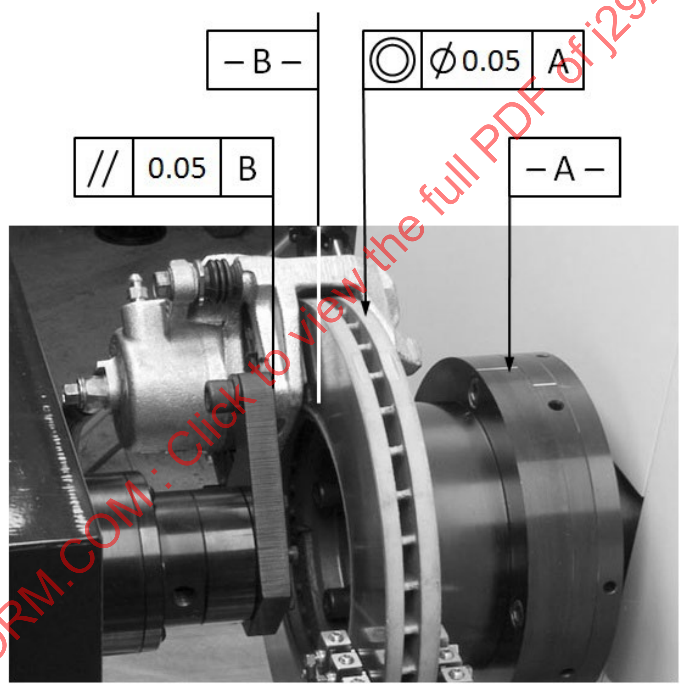


Figure 3 - Alignment specification for hubless test fixture

5.6 Control brake cooling air temperature to 25 °C ± 5 °C and humidity to 9.92 g/kg (11.57 g/m^3) at sea level. Use a psychrometric chart to find acceptable relative humidity conditions to meet absolute humidity requirements. If no environmental conditioning is available, record and report cooling air temperature and humidity during the test.

5.7 Park Brake Testing Capabilities (for Rear Brakes)

5.7.1 Ability to apply torque from zero shaft rotational speed sufficient to cause breakaway.

5.7.2 Mechanism to apply and control input park brake force or to energize the electric parking brake system as applicable.

5.7.3 Mechanism to lock the parking brake cable in position during parking brake output evaluation.

6. TEST CONDITIONS AND SAMPLE PREPARATION

6.1 Use new rotor and brake pads for each test.

6.2 Use brake pads as provided or instructed by the test requestor. Alternatively, and to characterize the brake drag contribution of other brake components, use friction materials with a coefficient of friction known from prior tests.

6.3 For brake rotors, install thermocouple at a depth of 1.0 mm on the outboard face near the centerline of the braking surface.

6.4 For brake pads, install one thermocouple at a depth of 2.0 mm near the center of the friction surface. For disc brake pads with grooves, install the thermocouple at least 4.0 mm from the groove edge on the leading side of the pad.

6.5 For disc brakes, unless otherwise specified, the assembled lateral run-out shall not exceed 50 µm when measured on the outboard surface and 10 mm from the outside diameter. If other lateral run-out is specified for the project, document it and include it on the final test report.

6.6 Calculate dynamometer rotational speed based on the tire dynamic rolling radius per SAE J2789.

6.7 Set cooling air temperature and humidity per 5.6.

6.8 Measure the lining and rotor thickness before and after test completion per SAE J2986.

6.9 Measure rotor LRO and DTV before and after the test at three radial locations:

6.9.1 10 mm from the rotor outside diameter.

6.9.2 Centerline (offset from the radial position from the thermocouple location).

6.9.3 10 mm from the braking surface inside diameter.

(Optional) Leave the probe rack installed for the entire test to measure the LRO and DTV evolution throughout the test.

If available, use any SAE standard on how to measure LRO and DTV; otherwise, agree with the test requestor on an agreeable method.

7. DYNAMOMETER TEST INERTIA

Unless provided by the test requestor, determine test inertia per appropriate item from SAE J2789 at GVWR.

8. TEST SEQUENCES FOR DIFFERENT BRAKES AND SCHEDULES

Tables 2A and 2B depict all the different options and schedules for disc and drum brakes. It is incumbent upon the test requestor to define the schedules applicable to the project.

Table 2A - Flowchart for the different methods and schedules

Testing Schedules	Description
A.1 Default	Revised test procedure from 2016 version used to evaluate drag behavior at different temperatures and speed. The pressure/speed sequence have been modified and removed the reverse direction.
B **(Optional)** Hot Drag	Drag evaluation after exposure of severe high temperatures.
C **(Optional)** Parking Brake	Evaluation of the parking brake influence on drag.

Table 2B - Flowchart for the different methods and schedules

Testing Schedules	Description
A.2 BEV/Hybrid and EMB	Schedule A.1 modified to run some sections with a driving cycle (WLTP) that is decel control, utilizing the dynamometer regen capabilities to simulate hydrid, battery electric vehicle (BEV), and electromechanical brake (EMB) configurations. Allowing them to be tested.
B **(Optional)** Hot Drag	Drag evaluation after exposure of severe high temperatures.
C **(Optional)** Parking Brake	Evaluation of the parking brake influence on drag.

9. TEST PROCEDURES

9.1 Piston Retraction

In order to properly determine brake drag measurements, quantify system losses at the start of the test, and avoid excessive loading on the brake components, perform the following steps:

9.1.1 Connect the brake to the hydraulic brake application system.

9.1.2 Perform the brake bleed per the brake manufacturer specification or per the test requestor. Integral park brake bleed procedure may have specific steps in addition to the steps required for service brakes. In case fluid displacement (or apparent piston travel) versus brake pressure curves are available, verify the dynamometer bleed before proceeding to the main test sequence.

9.1.3 Ensure all brake valves connecting the brake to the brake pressure source are in the open position.

9.1.4 Unless otherwise specified by the test requestor, and without disturbing the caliper guide pins or other hardware, provide clearance between the pads and the rotor by:

9.1.4.1 Use a hand press (preferably made out of plastic) to retract the piston and pads.

9.1.4.2 Mount the caliper assembly onto the fixture.

9.1.4.3 Measure the running clearance using shim(s) to achieve a 0.5- to 1.0-mm running clearance between each pad and the rotor.

9.1.4.4 Remove the shim(s) and then rotate the brake rotor slowly by hand for at least three revolutions to ensure a free-running condition.

9.2 Brake Drag Test Matrix at Ambient Temperature

Measure brake drag after a series of static brake applications and brake dynamic events per Table 3.

9.2.1 During each of the 130-second brake drag measurements, record the entire brake drag event only during the forward driving conditions. Reverse operations (indicated by a negative sign on the braking speed on the test matrix) are only used to provide caliper and brake corner conditioning.

9.2.2 Do not apply brake pressure to control dynamometer speed or to decelerate the shaft to change brake rotation between dynamic brake drag measurements.

9.2.3 When using a fixture with a hub bearing (see 5.5), conduct a 30-minute rotation at 80 km/h to stabilize the bulk temperature on the bearing. Repeat this bearing warm-up when the test is interrupted and the hub bearing reaches ambient temperature.

9.2.4 (Optional) Record the bearing temperature to ensure it is constant during the entire tests. If the temperature drops below 5° of the average defined temperature, rerun the warm-up of the bearing.

9.2.5 (Optional) To better understand caliper piston behavior, manually fully retract the pistons before each brake static pressure section. This will enable a reset of the piston and provide better comparison of drag effect at different pressures as the matrix is performed. The use of piston retractions throughout the test shall be documented clearly in the test report.

9.2.6 Alternatively, conduct the dynamic braking in the reverse direction at 2000 kPa. Conduct with the test requestor prior to commence testing.

9.3 Brake Cooling Speed

Rotate the rotor at 10 km/h between dynamic brake drag measurements to achieve the initial brake temperature for the next step.

Table 3 - Brake drag matrix at ambient temperature

Step Number	Section Description	Braking Release Speed [km/h]	Brake Application Control (IBT, Cycle Time, or Distance)	Dynamic Pressure [kPa]	Deceleration Level [g]	Static Pressure [kPa]	# of Stops/Snubs
1.1	Brake Drag 500 kPa at 20 km/h	0-0	IBT < 35 °C	-	-	500 10 seconds at pressure	1
1.2		20	IBT < 35 °C 130 seconds at speed	-	-	Brake drag measurement only	1
1.3	Repeat steps 1.1 and 1.2 two more times.						
1.4	Brake Drag 500 kPa at 30 km/h	0-0	IBT < 35 °C	-	-	500 10 seconds at pressure	1
1.5		30	IBT < 35 °C 130 seconds at speed	-	-	Brake drag measurement only	1
1.6	Repeat steps 1.4 and 1.5 two more times.						
1.7	Brake Drag 500 kPa at 60 km/h	0-0	IBT < 35 °C	-	-	500 10 seconds at pressure	1
1.8		60	IBT < 35 °C 130 seconds at speed	-	-	Brake drag measurement only	1
1.9	Repeat steps 1.7 and 1.8 two more times.						
1.10	Brake Drag 500 kPa at 120 km/h	0-0	IBT < 35 °C	-	-	500 10 seconds at pressure	1
1.11		120	IBT < 35 °C 130 seconds at speed	-	-	Brake drag measurement only	1
1.12	Repeat steps 1.10 and 1.11 two more times.						
2.1	Brake Drag 1000 kPa at 20 km/h	0-0	IBT < 35 °C	-	-	1000 10 seconds at pressure	1
2.2		20	IBT < 35 °C 130 seconds at speed	-	-	Brake drag measurement only	1
2.3	Repeat steps 2.1 and 2.2 two more times.						
2.4	Brake Drag 1000 kPa at 30 km/h	0-0	IBT < 35 °C	-	-	1000 10 seconds at pressure	1

2.5		30	IBT < 35 °C 130 seconds at speed	-	-	Brake drag measurement only	1
2.6	Repeat steps 2.4 and 2.5 two more times.						
2.7	Brake Drag 1000 kPa at 60 km/h	0-0	IBT < 35 °C	-	-	1000 10 seconds at pressure	1
2.8		60	IBT < 35 °C 130 seconds at speed	-	-	Brake drag measurement only	1
2.9	Repeat steps 2.7 and 2.8 two more times.						
2.10	Brake Drag 1000 kPa at 120 km/h	0-0	IBT < 35 °C	-	-	1000 10 seconds at pressure	1
2.11		120	IBT < 35 °C 130 seconds at speed	-	-	Brake drag measurement only	1
2.12	Repeat steps 2.10 and 2.11 two more times.						
3.1	Brake Drag 2000 kPa at 20 km/h	0-0	IBT < 35 °C	-	-	2000 10 seconds at pressure	1
3.2		20	IBT < 35 °C 130 seconds at speed	-	-	Brake drag measurement only	1
3.3	Repeat steps 3.1 and 3.2 two more times.						
3.4	Brake Drag 2000 kPa at 30 km/h	0-0	IBT < 35 °C	-	-	2000 10 seconds at pressure	1
3.5		30	IBT < 35 °C 130 seconds at speed	-	-	Brake drag measurement only	1
3.6	Repeat steps 3.4 and 3.5 two more times.						
3.7	Brake Drag 2000 kPa at 60 km/h	0-0	IBT < 35 °C	-	-	2000 10 seconds at pressure	1
3.8		60	IBT < 35 °C 130 seconds at speed	-	-	Brake drag measurement only	1
3.9	Repeat steps 3.7 and 3.8 two more times.						
3.10	Brake Drag 2000 kPa at 120 km/h	0-0	IBT < 35 °C	-	-	2000 10 seconds at pressure	1
3.11		120	IBT < 35 °C 130 seconds at speed	-	-	Brake drag measurement only	1
3.12	Repeat steps 3.10 and 3.11 two more times.						
4.1	Brake Drag 3000 kPa at 20 km/h	0-0	IBT < 35 °C	-	-	3000 10 seconds at pressure	1
4.2		20	IBT < 35 °C 130 seconds at speed	-	-	Brake drag measurement only	1
4.3	Repeat steps 4.1 and 4.2 two more times.						
4.4	Brake Drag 3000 kPa at 30 km/h	0-0	IBT < 35 °C	-	-	3000 10 seconds at pressure	1
4.5		30	IBT < 35 °C 130 seconds at speed	-	-	Brake drag measurement only	1
4.6	Repeat steps 4.4 and 4.5 two more times.						
4.7	Brake Drag 3000 kPa at 60 km/h	0-0	IBT < 35 °C	-	-	3000 10 seconds at pressure	1
4.8		60	IBT < 35 °C 130 seconds at speed	-	-	Brake drag measurement only	1
4.9	Repeat steps 4.7 and 4.8 two more times.						
4.10	Brake Drag 3000 kPa at 120 km/h	0-0	IBT < 35 °C	-	-	3000 10 seconds at pressure	1
4.11		120	IBT < 35 °C 130 seconds at speed	-	-	Brake drag measurement only	1
4.12	Repeat steps 4.10 and 4.11 two more times.						
5.1	Brake Drag 6000 kPa at 20 km/h	0-0	IBT < 35 °C	-	-	6000 10 seconds at pressure	1
5.2		20	IBT < 35 °C 130 seconds at speed	-	-	Brake drag measurement only	1
5.3	Repeat steps 5.1 and 5.2 two more times.						

5.4	Brake Drag 6000 kPa at 30 km/h	0-0	IBT < 35 °C	-	-	6000 10 seconds at pressure	1
5.5		30	IBT < 35 °C 130 seconds at speed	-	-	Brake drag measurement only	1
5.6	Repeat steps 5.4 and 5.5 two more times.						
5.7	Brake Drag 6000 kPa at 60 km/h	0-0	IBT < 35 °C	-	-	6000 10 seconds at pressure	1
5.8		60	IBT < 35 °C 130 seconds at speed	-	-	Brake drag measurement only	1
5.9	Repeat steps 5.7 and 5.8 two more times.						
5.10	Brake Drag 6000 kPa at 120 km/h	0-0	IBT < 35 °C	-	-	6000 10 seconds at pressure	1
5.11		120	IBT < 35 °C 130 seconds at speed	-	-	Brake drag measurement only	1
5.12	Repeat steps 5.10 and 5.11 two more times.						
6.1	Brake Drag 8000 kPa at 20 km/h	0-0	IBT < 35 °C	-	-	8000 10 seconds at pressure	1
6.2		20	IBT < 35 °C 130 seconds at speed	-	-	Brake drag measurement only	1
6.3	Repeat steps 6.1 and 6.2 two more times.						
6.4	Brake Drag 8000 kPa at 30 km/h	0-0	IBT < 35 °C	-	-	8000 10 seconds at pressure	1
6.5		30	IBT < 35 °C 130 seconds at speed	-	-	Brake drag measurement only	1
6.6	Repeat steps 6.4 and 6.5 two more times.						
6.7	Brake Drag 8000 kPa at 60 km/h	0-0	IBT < 35 °C	-	-	8000 10 seconds at pressure	1
6.8		60	IBT < 35 °C 130 seconds at speed	-	-	Brake drag measurement only	1
6.9	Repeat steps 6.7 and 6.8 two more times.						
6.10	Brake Drag 8000 kPa at 120 km/h	0-0	IBT < 35 °C	-	-	8000 10 seconds at pressure	1
6.11		120	IBT < 35 °C 130 seconds at speed	-	-	Brake drag measurement only	1
6.12	Repeat steps 6.10 and 6.11 two more times.						
7.1	Brake Drag 12000 kPa at 20 km/h	0-0	IBT < 35 °C	-	-	12000 10 seconds at pressure	1
7.2		20	IBT < 35 °C 130 seconds at speed	-	-	Brake drag measurement only	1
7.3	Repeat steps 7.1 and 7.2 two more times.						
7.4	Brake Drag 12000 kPa at 30 km/h	0-0	IBT < 35 °C	-	-	12000 10 seconds at pressure	1
7.5		30	IBT < 35 °C 130 seconds at speed	-	-	Brake drag measurement only	1
7.6	Repeat steps 7.4 and 7.5 two more times.						
7.7	Brake Drag 12000 kPa at 60 km/h	0-0	IBT < 35 °C	-	-	12000 10 seconds at pressure	1
7.8		60	IBT < 35 °C 130 seconds at speed	-	-	Brake drag measurement only	1
7.9	Repeat steps 7.7 and 7.8 two more times.						
7.10	Brake Drag 12000 kPa at 120 km/h	0-0	IBT < 35 °C	-	-	12000 10 seconds at pressure	1
7.11		120	IBT < 35 °C 130 seconds at speed	-	-	Brake drag measurement only	1
7.12	Repeat steps 7.10 and 7.11 two more times.						

9.4 Test Procedure for Front Disc Brake

Table 4 illustrates the test schedule to assess brake drag on front axles. Unless otherwise specified by the test requestor, the default test does not require the execution of schedules B, C, or D.

9.4.1 (Optional) measure brake drag for 5 seconds immediately before applying hydraulic pressure and 5 seconds immediately after releasing brake pressure during dynamic brake applications.

NOTE: Consult with the test requestor and the test facility prior to testing to confirm the actual brake drag measurement time and to confirm the availability of such feature on the inertia-dynamometer.

Table 4 - Front and rear disc brake test procedure

Step Number	Section Description	Braking Release Speed [km/h]	Brake Application Control (IBT, Cycle Time, or Distance)	Dynamic Pressure [kPa]	Deceleration Level [g]	Static Pressure [kPa]	# of Stops/Snubs
SCHEDULE DISC A.1 - DEFAULT							
1	Initial setup and inspection	(optional) fingerprint caliper for sliding force, rollback, knockback. Set and measure rotor for: LRO and DTV					
2	Piston retraction	Perform piston retraction per 9.1					
3	Initial corner drag baseline	80-80	IBT = ambient	30 minutes **Assess torque signal stability and noise**			1
4	Green μ characteristic	80-30	IBT = 100 °C	3000	-	-	30
5-7	Brake drag (1-3)	Conduct brake drag test matrix at ambient temperature per Table 1					
8	Brake burnish	80-0.5	IBT = 100 °C	-	0.31	-	200
9-11	Brake drag (4-6)	Conduct brake drag test matrix at ambient temperature per Table 1					
12	Characteristic value (1)	80-30	IBT = 100 °C	3000	-	-	6
13	Speed/pressure sensitivity 40 km/h	40-0.5	IBT = 100 °C	1000, 2000, 3000, 4000, 5000, 6000, 7000, 8000	-	-	8
14	Speed/pressure sensitivity 80 km/h	80-40	IBT = 100 °C	1000, 2000, 3000, 4000, 5000, 6000, 7000, 8000	-	-	8
15	Speed/pressure sensitivity 120 km/h	120-80	IBT = 100 °C	1000, 2000, 3000, 4000, 5000, 6000, 7000, 8000	-	-	8
16	(Optional) Speed/pressure sensitivity 160 km/h	160-130	IBT = 100 °C	1000, 2000, 3000, 4000, 5000, 6000, 7000, 8000	-	-	8
17	(Optional) Speed/pressure sensitivity 200 km/h	200-170	IBT = 100 °C	1000, 2000, 3000, 4000, 5000, 6000, 7000, 8000	-	-	8
18	Characteristic value (2)	80-30	IBT = 100 °C	3000	-	-	6
19	Cold application	40-0.5	IBT < 40 °C	3000	-	-	1
20	Highway applications	100-0.5	IBT = 50 °C	-	0.6	-	1
		0.90·Vmax - 0.5·Vmax	IBT = 50 °C	-	0.6	-	1

21	Characteristic value (3)	80-30	IBT = 100 °C	3000	-	-	6
22	Fade (1)	100-0.5	IBT = < 100, <215, < 283, <330, <367, <398, <423, <446, <465, <483, <498, <513, <526, <539, <550.	< 16000	0.4	-	15
23-25	Brake drag (7-9)	Conduct brake drag test matrix at ambient temperature per Table 1					
26	Recovery (1)	80-30	IBT = 100 °C	3000	-	-	18
27	Temperature/pressure sensitivity 100 °C	80-30	IBT = 100 °C	1000, 2000, 3000, 4000, 5000, 6000, 7000, 8000	-	-	8
28	Temperature/pressure sensitivity 500 °C	80-30	IBT = < 100, <150, < 200, <250, <300, <350, <400, <450, <500.	3000	-	-	9
29	Pressure line 500 °C	80-30	IBT = 50 °C	1000, 2000, 3000, 4000, 5000, 6000, 7000, 8000	-	-	8
30	Recovery (2)	80-30	IBT = 100 °C	3000	-	-	18
31	Fade (2)	100-0.5	IBT = < 100, <215, < 283, <330, <367, <398, <423, <446, <465, <483, <498, <513, <526, <539, <550.	< 16 000	0.4	-	15
32-34	Brake drag (10-12)	Conduct brake drag test matrix at ambient temperature per Table 1					
35	Recovery (3)	80-30	IBT = 100 °C	3000	-	-	18
36	Final inspection for main test sequence	Measure parts for: LRO, DTV, taper, cup, and tangential wear (optional) fingerprint caliper for sliding force, rollback, knockback					
37[1]	Final corner drag baseline	80-80	IBT = ambient	30 minutes **Assess torque signal stability and noise**			1
End of test Schedule disc A							
(OPTIONAL) SCHEDULE DISC B - HOT DRAG							
38	Hot drag heating cycle to 500 °C	65-1	IBT = first at ambient, then until reaching 500 °C		0.35		As need to reach 500 °C without excedding 50
39	Hot drag temperature stabilization at 500 °C	65-1	IBT = 500 °C		0.35		30
40	Hot drag static application	0-0	IBT = 450 °C			14000 10 seconds at pressure	1
41	Hot drag static measurement	10 130 seconds measurement	Start within 10 seconds after release of static application				1
42-77	Hot drag (400 to 60) °C	Repeat steps 40-41 at 20 °C intervals of brake pad temperature until reaching 60 °C					
78	Brake drag (13)	Retract pistons Conduct one brake drag test matrix at ambient temperature per Table 1					

79	Post hot-drag inspection	Measure parts for: LRO, DTV, taper, cup, and tangential wear (optional) fingerprint caliper for sliding force, rollback, knockback					
80(1)	Final corner drag baseline	80-80	IBT = ambient	30 minutes **Assess torque signal stability and noise**			1
End of test Schedule disc B							
(OPTIONAL) SCHEDULE DISC C - Parking Brake							
80.1	Integral park brake - light apply	0-0	IBT = ambient	-	-	0 kPa service brake. Apply parking brake 1/3 maximum load for 10 seconds.	1
80.2		50-50	IBT = ambient 130 seconds at braking speed			Zero (0)	1
80.3		0-0	IBT = ambient	-	-	0 kPa service brake. Apply parking brake 1/3 maximum load for 10 seconds.	1
80.4		120-120	IBT = ambient 130 seconds at braking speed			Zero (0)	1
81.1	Integral park brake - moderate apply	0-0	IBT = ambient	-	-	0 kPa service brake. Apply parking brake 2/3 maximum load for 10 seconds.	1
81.2		50-50	IBT = ambient 130 seconds at braking speed			Zero (0)	1
81.3		0-0	IBT = ambient	-	-	0 kPa service brake. Apply parking brake 2/3 maximum load for 10 seconds.	1
81.4		120-120	IBT = ambient 130 seconds at braking speed			Zero (0)	1
82.1	Integral park brake - heavy apply	0-0	IBT = ambient	-	-	0 kPa service brake. Apply parking brake maximum load for 10 seconds.	1
82.2		50-50	IBT = ambient 130 seconds at braking speed			Zero (0)	1
82.3		0-0	IBT = ambient	-	-	0 kPa service brake. Apply parking brake maximum load for 10 seconds.	1
82.4		120-120	IBT = ambient 130 seconds			Zero (0)	1